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Injection molded polymer chip for electrochemical and electrophysiological recordings from single cells

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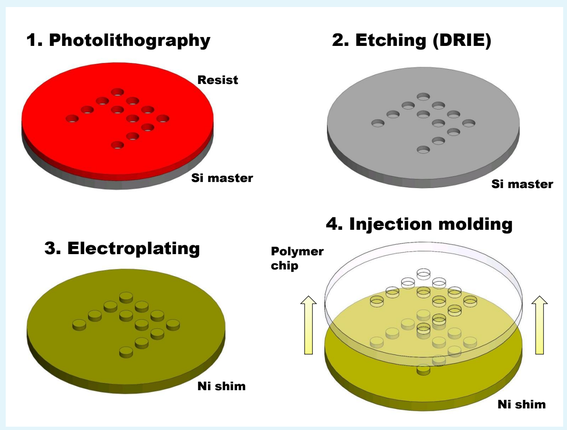
We present a novel method to fabricate an all in polymer injection molded chip for electrochemical cell recordings and lateral cell trapping. The complete device is molded in thermoplastic polymer and it results from assembling two halves. We tested spin-coated conductive polymer poly(3,4-ethylenedioxythiopene) and showed that it can be used as an electrode material for detecting neurotransmitters electrochemically in biosensors.

Device concept

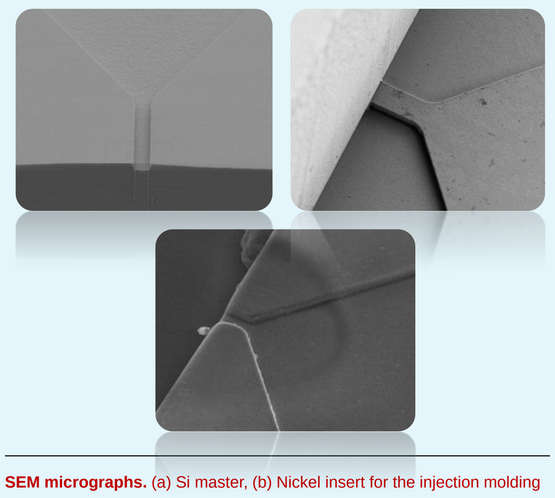
The chip design was inspired by the so-called mouse-hole configuration [1] where a hole through a fluidic compartment wall results from from assembling two halves; one half has an open channel structure and the other half has flat surface. This creates a microfluidic junction between a main chamber and a lateral recording capillary.

Microfabrication

The chips were fabricated using the UV-LIGA process [2,3], however here we used a Si master that was etched in a Deep Reactive Ion Etch (DRIE) system. The process includes photolithography for master origination of fluidic channels, electroplating of Si-master for Ni shim fabrication, injection molding for replication of the master, plasma assisted thermal bonding of parts for assembling the chip [4]. Parts were injection molded from TOPAS Cyclic Olefin Copolymer (COC).



Chip preparation, concept desing and test. (a) UV-LIGA process. Photolithography and DRIE etching for Si master origination, Electroplating for Nichel shim fabrication and Injection molding for replication of the master. (b) Schematic of so-called mouse-hole configuration. (c) 10 µm diameter polystyrene bead patch on a test PDMS replica.



SEM micrographs. (a) Si master, (b) Nickel insert for the injection molding machine, (c) injection molded polymer part.

Proof of concept

Polydimethylsiloxane (PDMS) replicas have been made from the Nickel shim in order to demonstrate the feasibility of the lateral cell trapping with the chosen geometry. Single polystyrene microbeads (10 µm diameter) have been trapped at the end of the channel by applying suction to the capillary.

Polymer electrodes

Electrodes to be used for electrochemical recordings were applied to the flat part of the TOPAS chip before bonding. Due to the relatively low melting temperature of the polymer substrate, electrode fabrication procedures that involve heating to high temperatures can not be used. Our electrodes are made of conducting polymer PEDOT which was spin-coated and patterned with standard photolithography. PEDOT microelectrodes with widths between 4 and 50 microns were fabricated and tested.

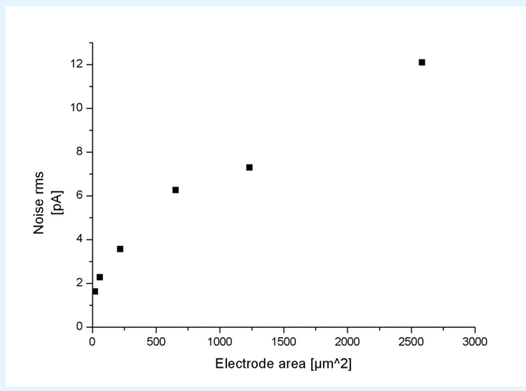


Figure 5: Noise versus electrode area. The noise was calculated as the root mean square noise of a current trace with the electrode being exposed to phosphate buffer.

They show a high capacitance compared to other thin film electrodes of 1670+-130 µF/cm^2, while the sheet resistance lies around 100 Ω.

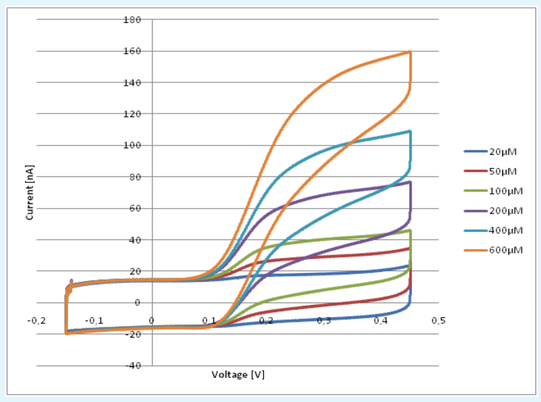


Figure 4: Cyclic voltammograms showing the oxidation of dopamine on a PEDOT electrode. Dopamine was diluted in PBS buffer. Scan rate: 10 mV/s, electrode dimensions: 50 µm X 1500 µm.. The large hysteresis is due to the high capacitance of PEDOT

Electrochemical recordings

Oxidation of the neurotransmitter Dopamine was done with different concentrations using slow scan cyclic voltammetry. The scans show that dopamine is readily oxidized, although the oxidation potential seems to be slightly lower than on carbon and platinum electrodes. When PEDOT microelectrodes are used for low noise amperometric measurements, the noise depends on the area of the electrodes. By making the electrode surface sufficiently small, noise levels below 2 pA can be reached.

References:

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